US006171437B1

(12) **United States Patent**
Shimizu et al.

(10) **Patent No.: US 6,171,437 B1**
(45) **Date of Patent: Jan. 9, 2001**

(54) **SEMICONDUCTOR MANUFACTURING DEVICE**

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(*) Notice: Under 35 U.S.C. 154(b), the term of this patent shall be extended for 0 days.

(21) Appl. No.: **09/197,585**

(22) Filed: **Nov. 23, 1998**

(30) **Foreign Application Priority Data**

Nov. 20, 1997 (JP) 9-320187

(51) **Int. Cl.**[7] **H05H 1/00**
(52) **U.S. Cl.** **156/345**; 118/728
(58) **Field of Search** 156/345, 637, 156/647; 216/91, 83; 134/34, 60, 94.1, 114, 135; 250/306; 437/225, 230; 427/2.1, 2.11; 118/728; 73/31.04, 747, 299

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,275,690 * 1/1994 Garwood, Jr. 156/637
5,437,757 * 8/1995 Rice et al. 118/728
5,542,559 * 8/1996 Kawakami et al. 118/728
5,695,566 * 12/1997 Suzuki et al. 118/728

* cited by examiner

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(57) **ABSTRACT**

A semiconductor manufacturing device comprises a holder having sealing members and supporting a semiconductor substrate so that an open space is formed above the semiconductor substrate and a sealed space is formed below the semiconductor substrate. The semiconductor substrate has a first main surface exposed to the open space and a second main surface exposed to the sealed space. When the holder is immersed in an etching solution, the first main surface of the semiconductor substrate is exposed to the etching solution and subjected to wet etching while the etching solution does not flow into the sealed space.

24 Claims, 4 Drawing Sheets

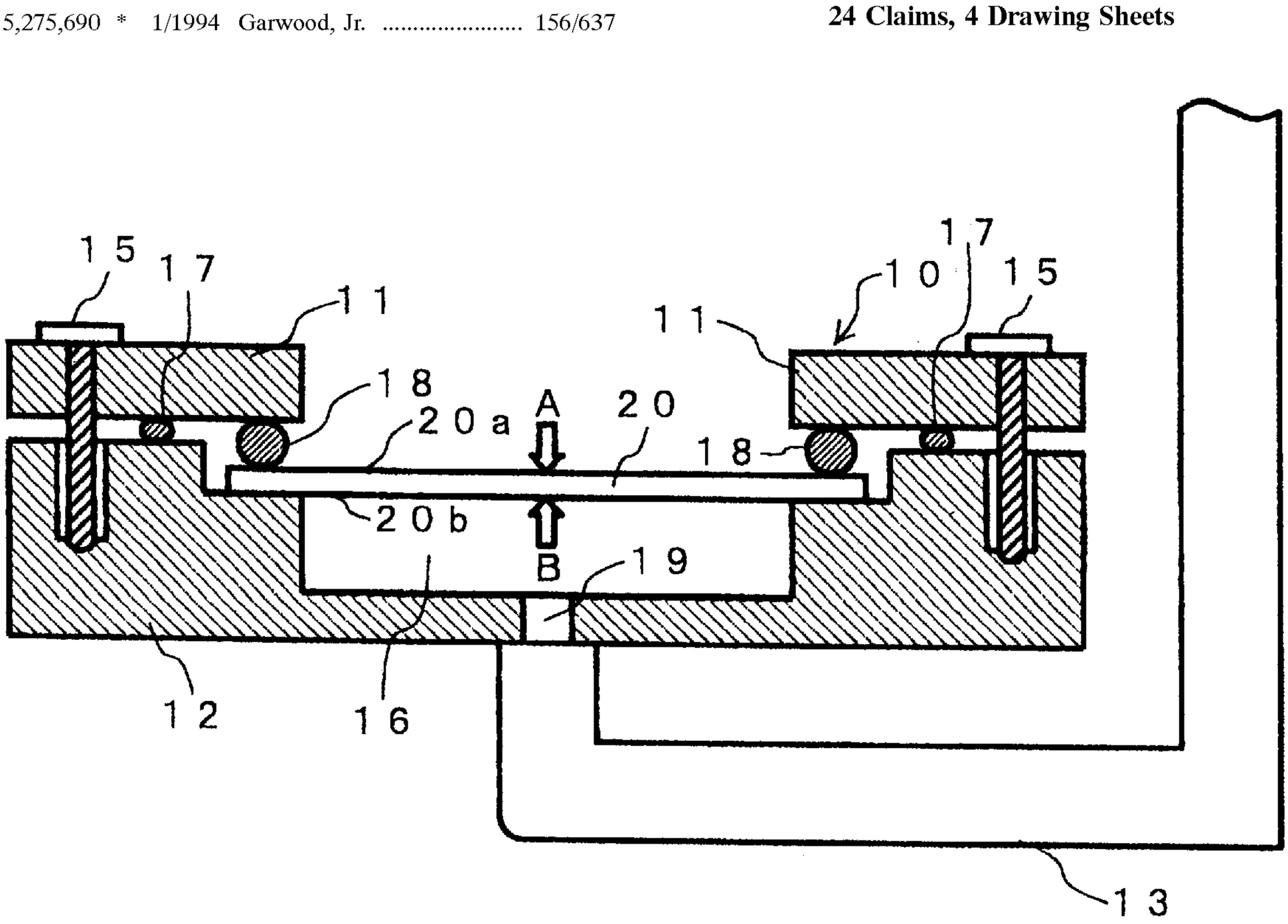


FIG. 1

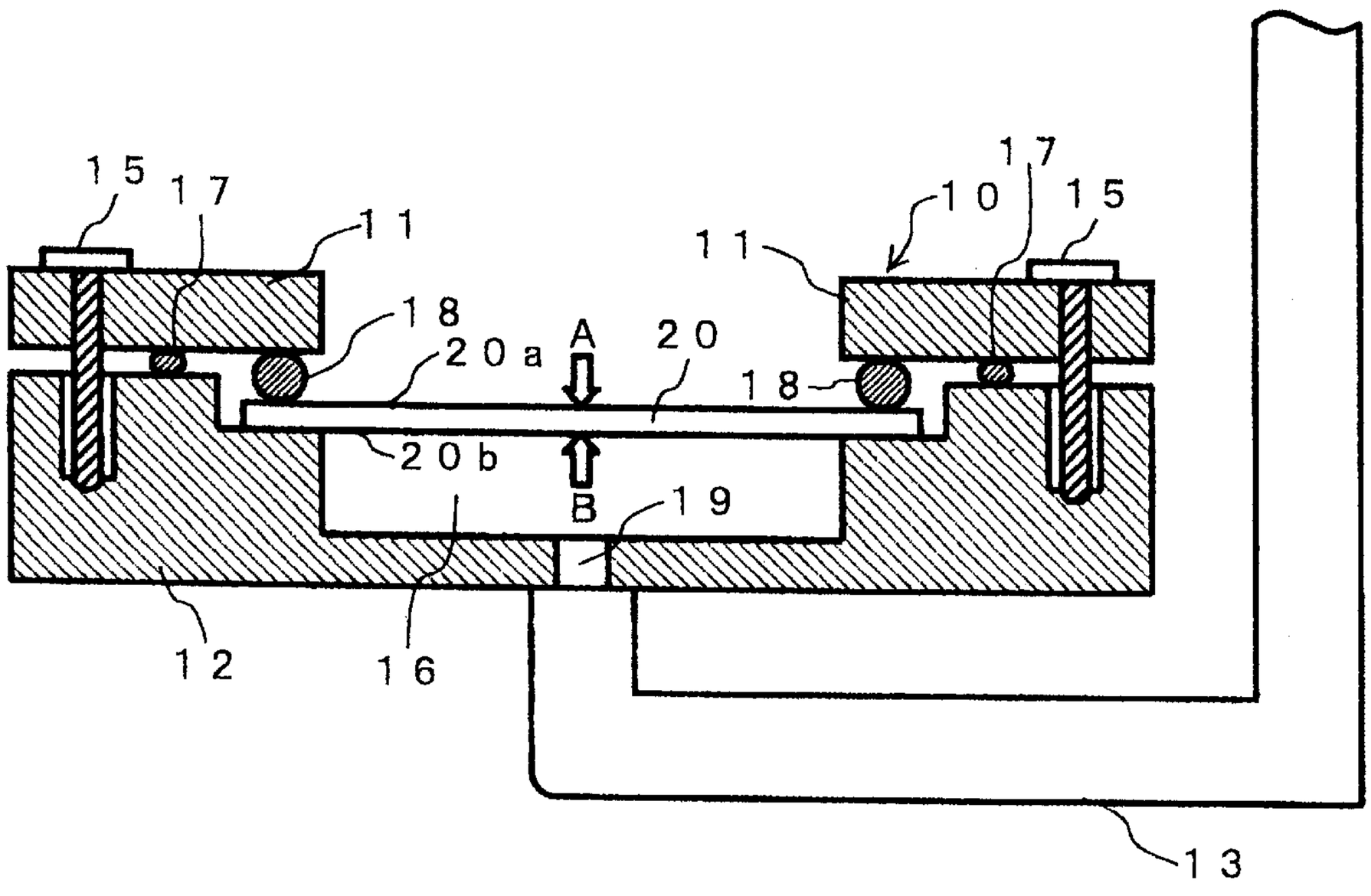

15
17
11
18
20a
A
20
20b
B
19
12
16
10
17
15
11
18
13

FIG. 2

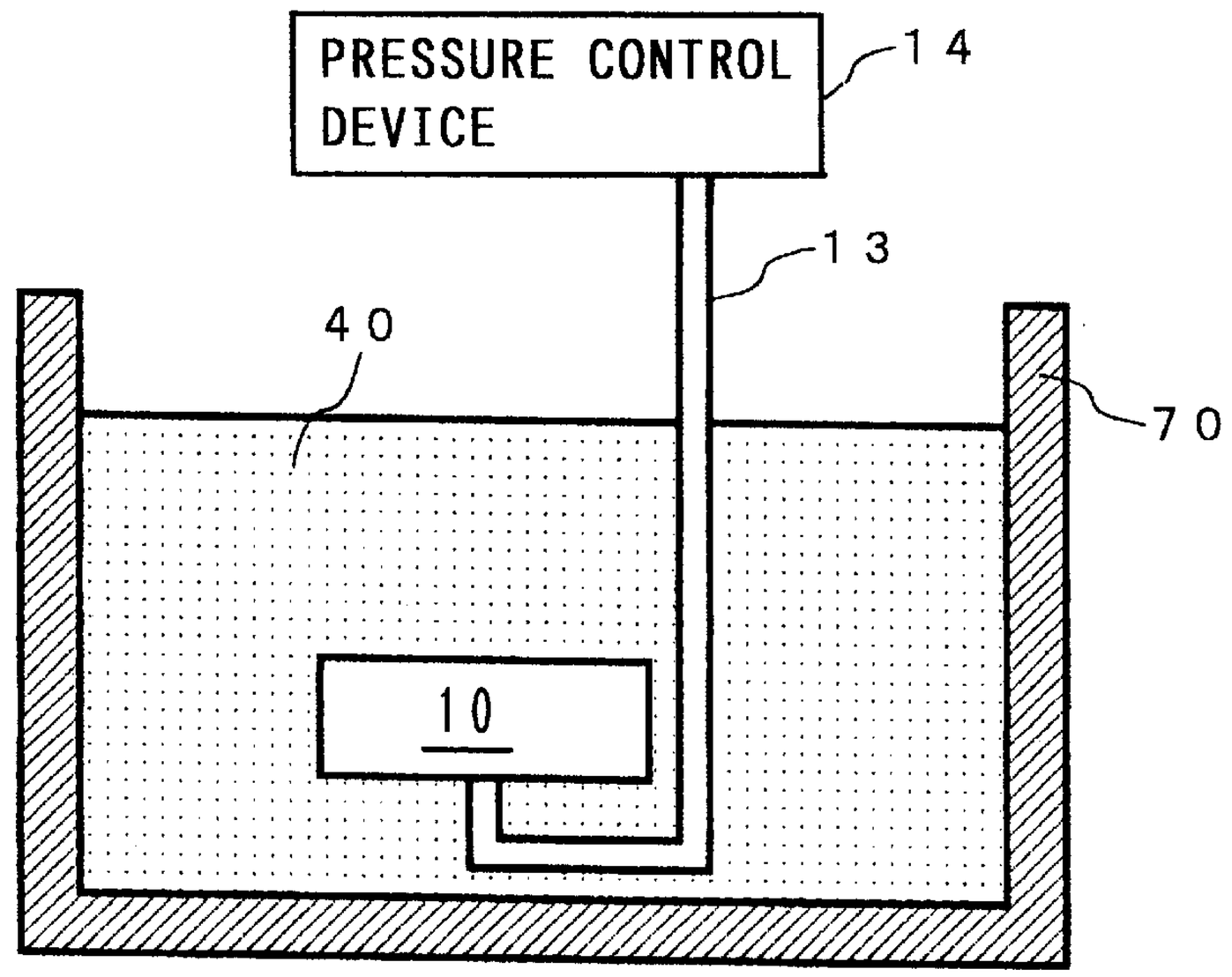

PRESSURE CONTROL DEVICE
14
13
40
70
10

FIG.3

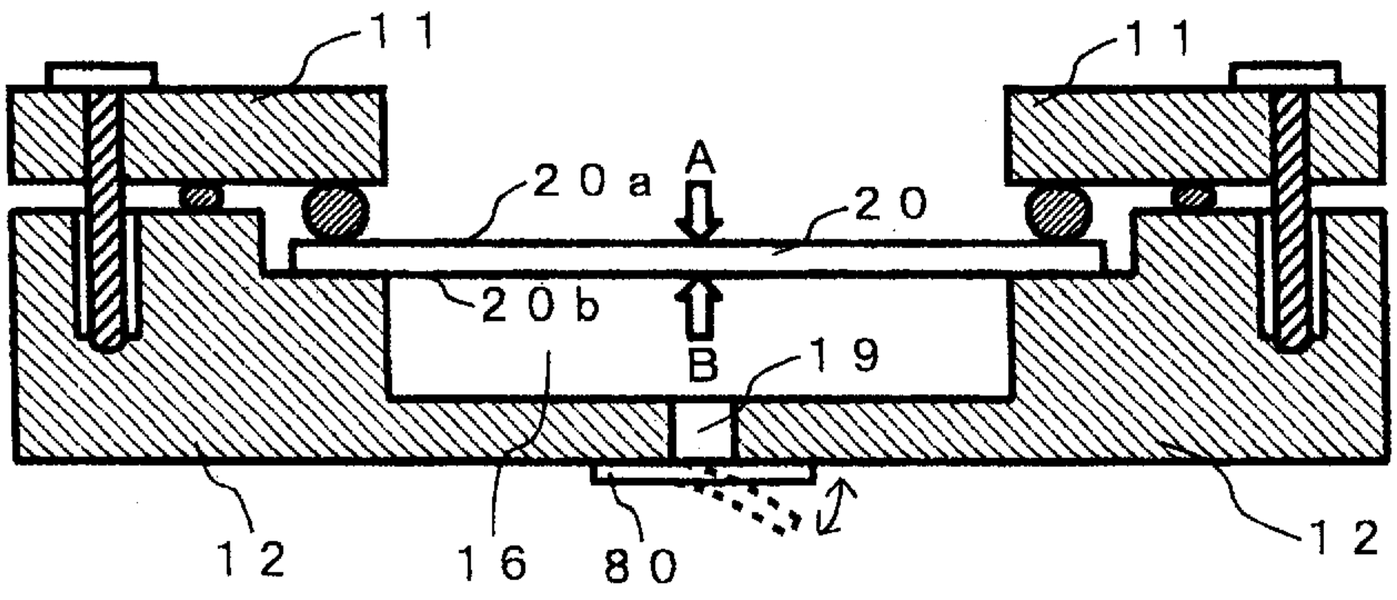

11
11
20a
A
20
20b
B
19
12
16
80
12

FIG.4

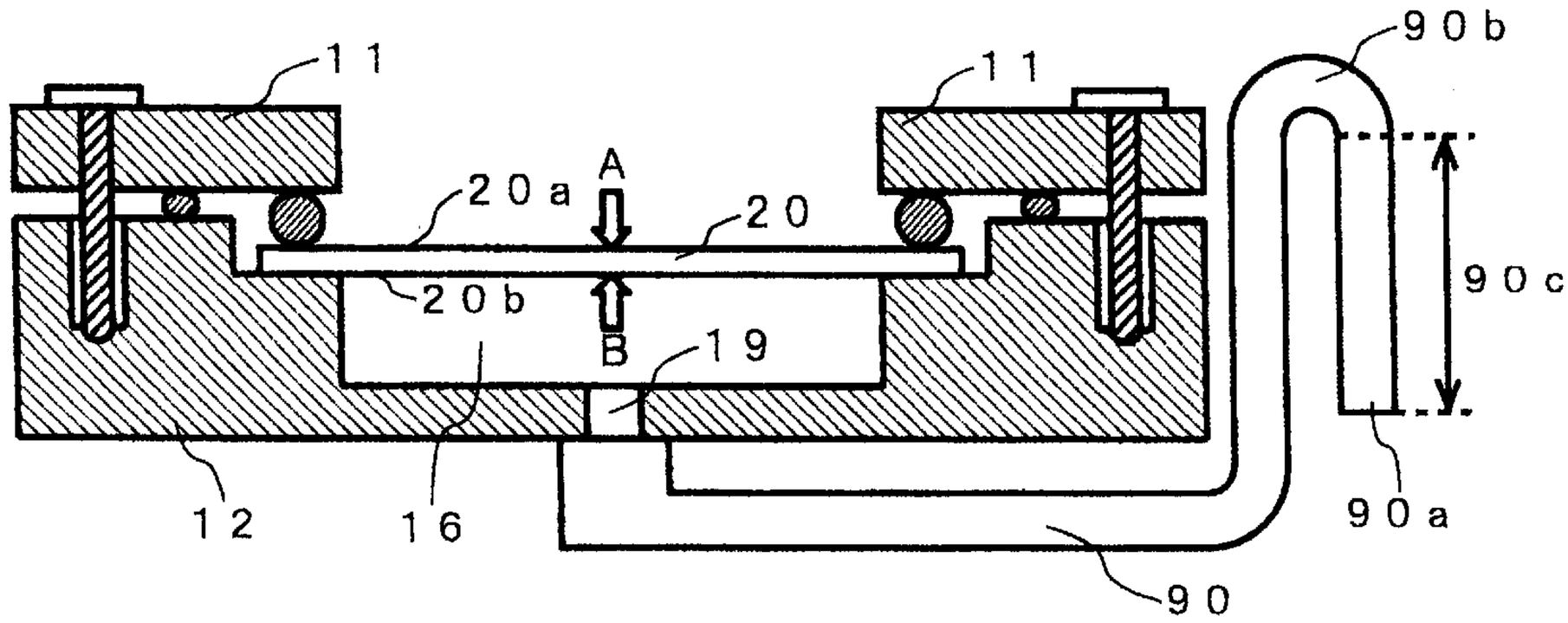

11
11
90b
20a
A
20
90c
20b
B
19
12
16
90a
90

FIG.5

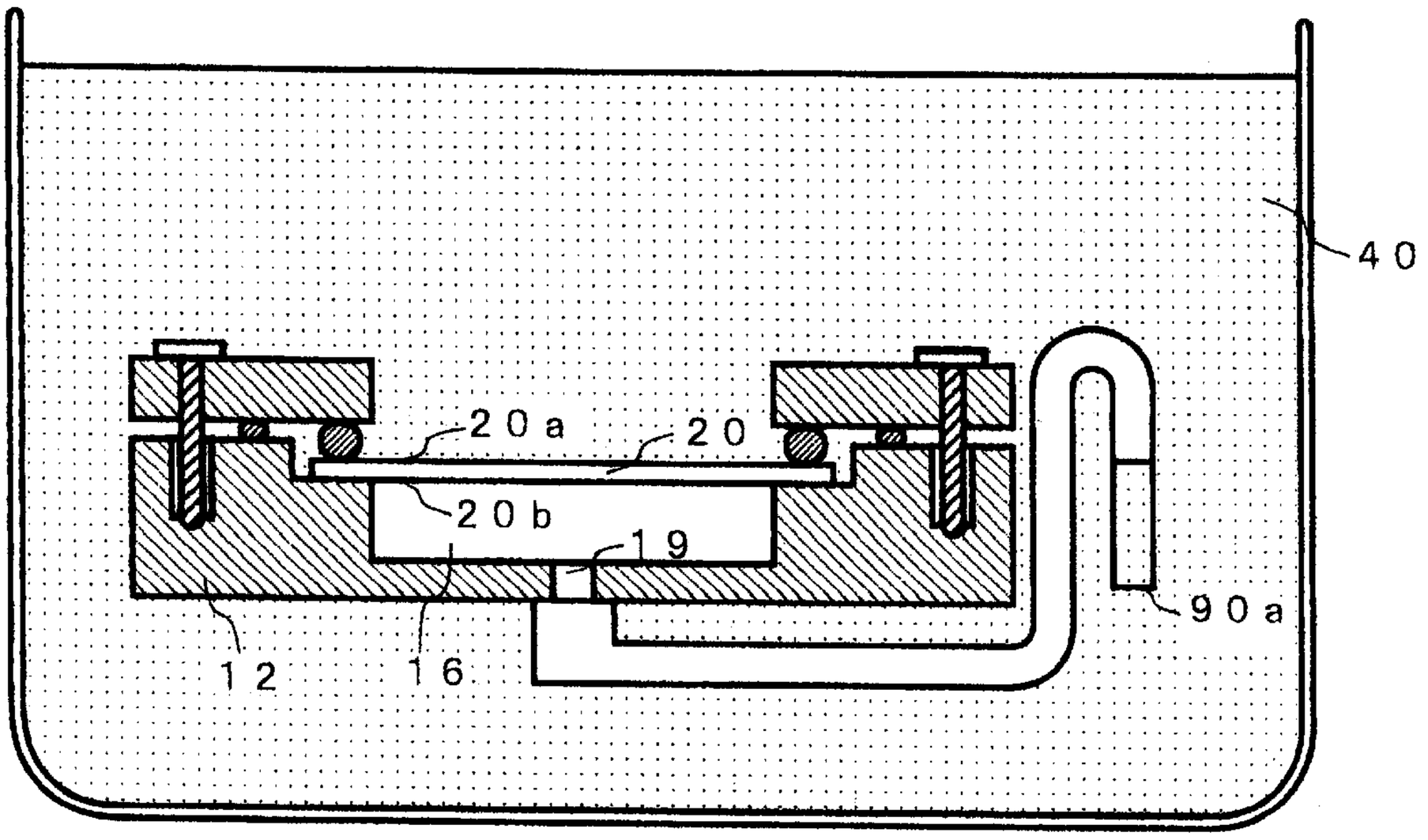


FIG.6

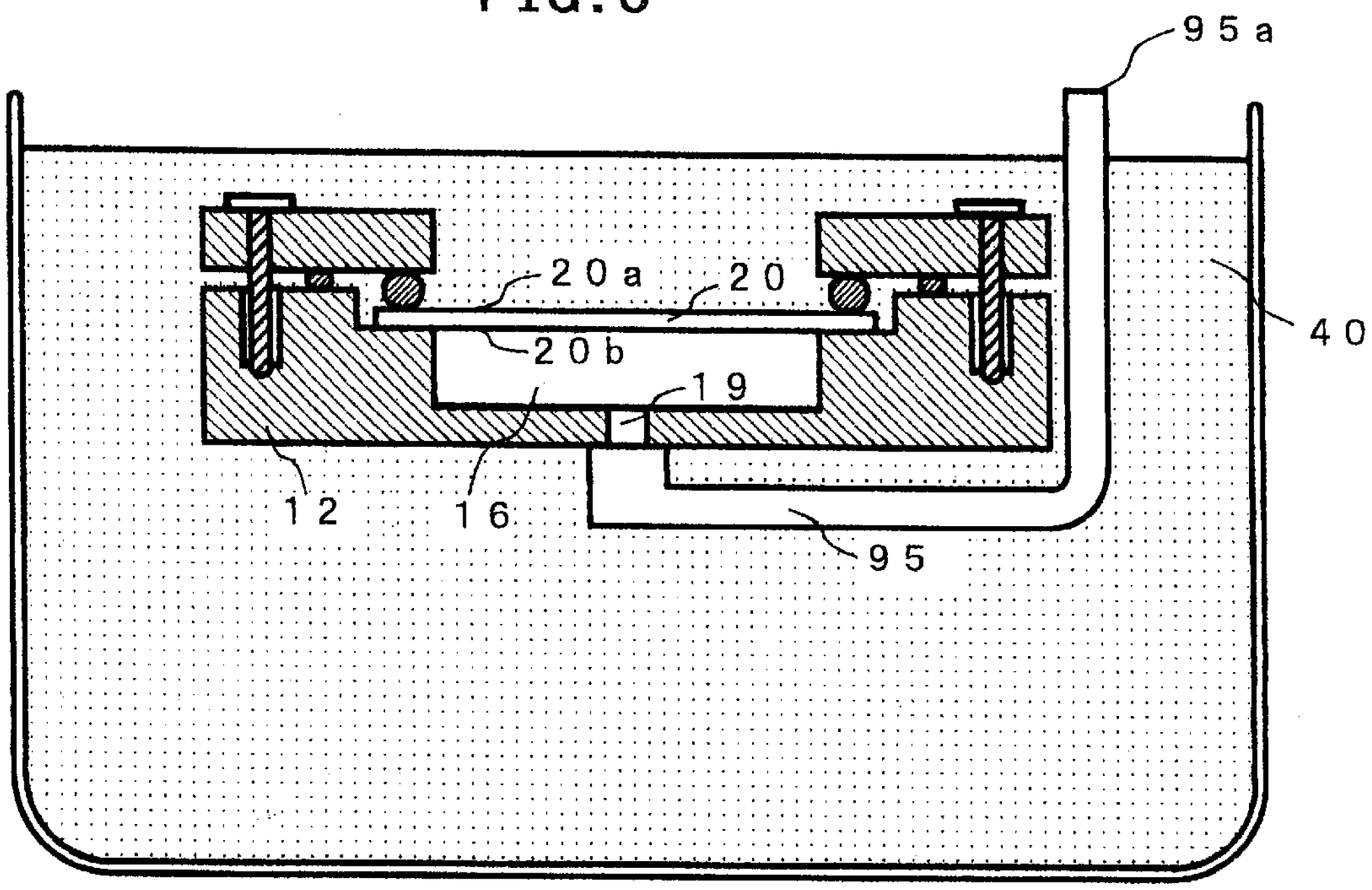


FIG. 7A
PRIOR ART

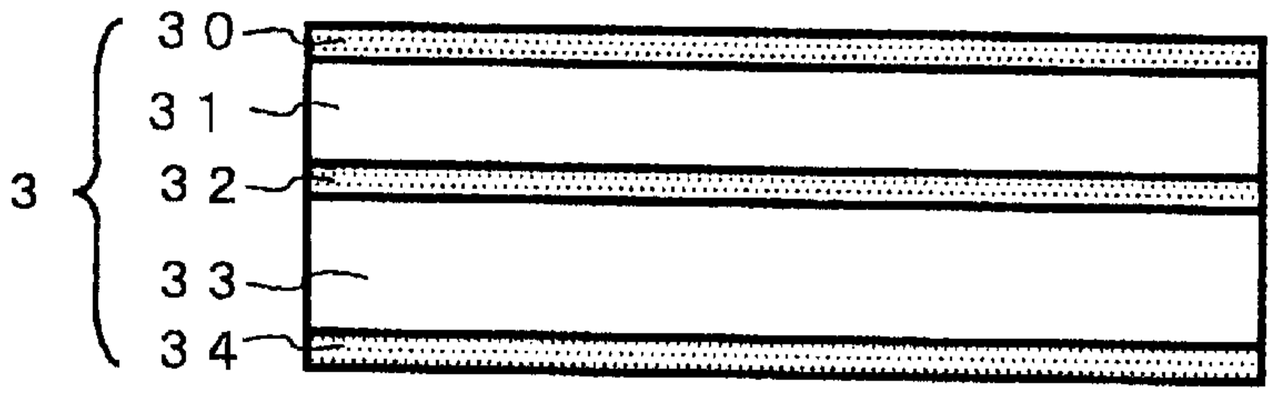


FIG. 7B
PRIOR ART

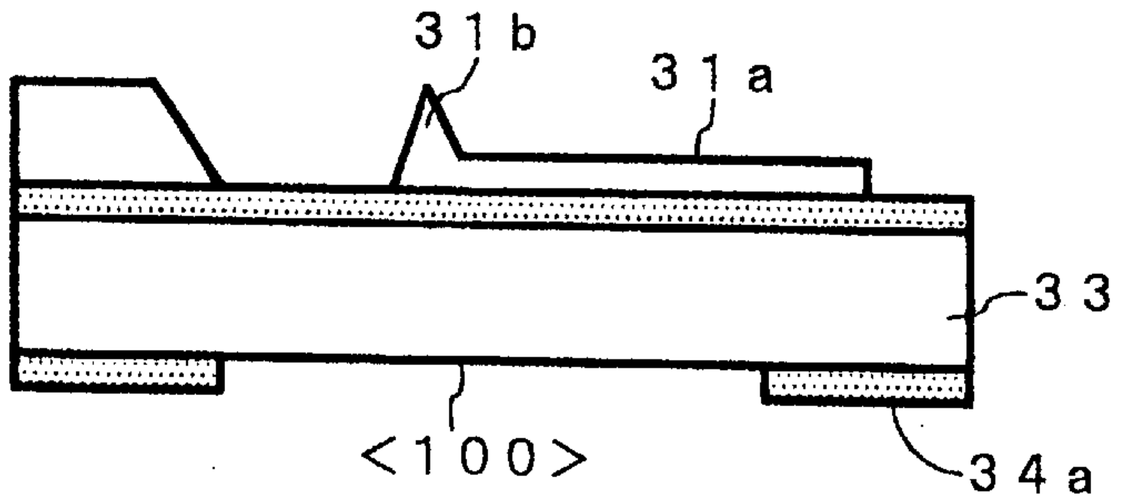


FIG. 7C
PRIOR ART

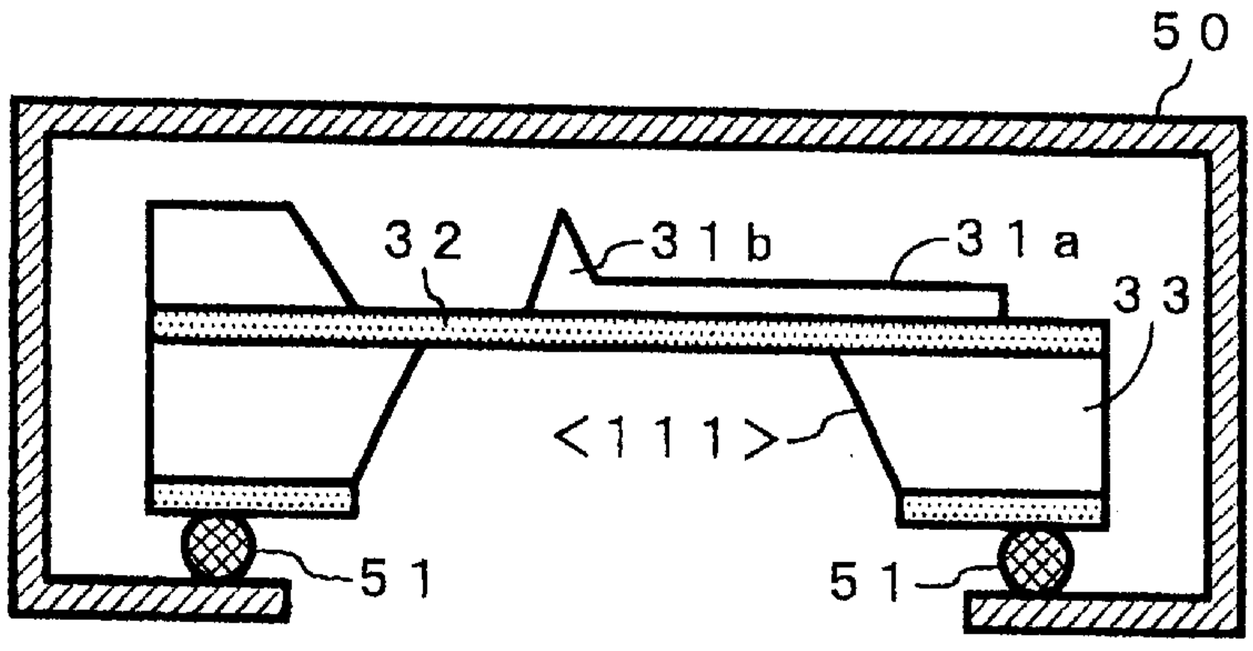
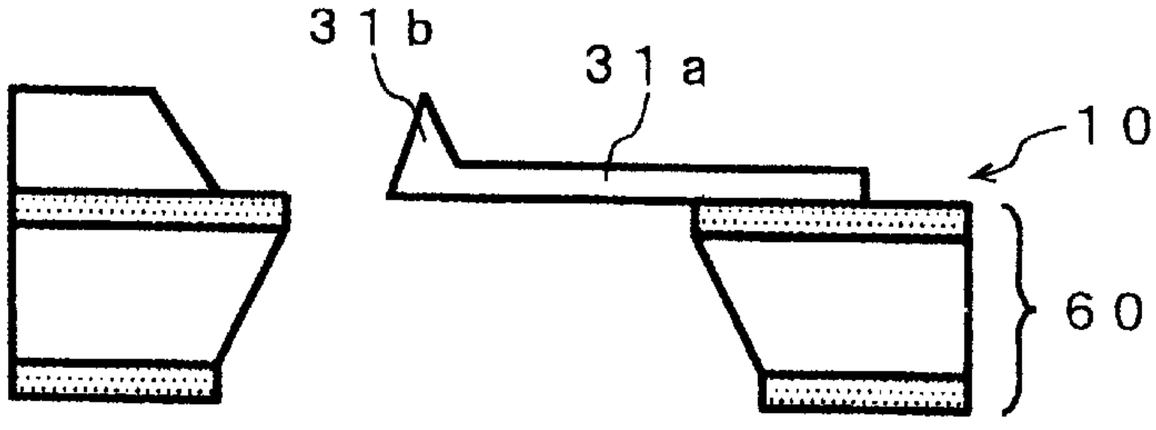


FIG. 7D
PRIOR ART



SEMICONDUCTOR MANUFACTURING DEVICE

BACKGROUND OF THE INVENTION

The present invention relates to a semiconductor manufacturing device for performing wet etching only on one main surface of a semiconductor substrate, particularly a semiconductor manufacturing device suitable for producing a cantilever used for a probe of a scanning probe microscope.

In a scanning probe microscope represented by an atomic force microscope (AFM), a cantilever in which an exploring needle is formed at a free end of a beam portion is used as a scanning probe. In the configuration, because attraction or repulsion based on interatomic force appears between a surface of a sample and the exploring needle by scanning the exploring needle on the surface of the sample, a shape of the surface of the sample can be measured by detecting the interatomic force as a deflection of the cantilever.

FIGS. **7**A to **7**D are sectional views showing a method of processing the conventional cantilever as a specimen. First as shown in FIG. **7***a*, layered substrate **3** is prepared, which is layered with a SiO_2 film **30**, a silicon thin film **31** acting as a beam portion of the cantilever and an exploring needle, a SiO_2 film **32** as an intermediate layer, a silicon substrate **33** acting as a supporting table of the cantilever, and a SiO_2 film **34**.

Next, a beam portion **31***a* of the cantilever and an exploring needle **31***b* are formed on a surface of the SiO_2 film **34** by etching SiO_2 film **30** into a proper shape so as to become a protecting film and by etching the silicon substrate **31** as the mask of the protecting film as shown in FIG. **7**B. Moreover, SiO_2 film **34** is properly etched so as to form a protecting film **34***a*, and surface <100> of the silicon substrate **33** is exposed.

Next, an end portion of layered substrate **3** is supported with a jig (etching holder) **50** sealed with an O-ring **51** for preventing inflow of liquid so that only the other main surface where said beam portion **31***a* and the exploring needle **31***b* of the layered substrate **3** is not formed is exposed by etching solution as shown in FIG. **7**C. SiO_2 film **32** exposes by etching the silicon substrate **33** as a mask of the protecting film **34** (**34***a*) using anisotropic wet-etching.

For the etching solution, a potassium hydroxide (KOH) aqueous solution of 40 percentage by weight at 60 to 80° C. a tetraalkylammonium hydroxide (TMAH) aqueous solution of 20 percentage by weight at 80 to 90° C., and so on can be used. With these etching solutions, plane <100> of the silicon substrate **33** is etched much faster than plane <111> so that the protecting film **34***a* is not actually etched. Therefore, anisotropic wet-etching actually stops at plane <111> referenced with the end of the protecting film **34***a*. At the end, the extra SiO_2 film **32** is removed as shown in FIG. **7**D. By the above-described process, a cantilever is completed which has an exploring needle **31***b* at one end of the beam portion **31***a* and the other portion thereof is supported by a cantilever-like supporting table **60**.

In the above-mentioned prior art, pressure increases corresponding to the depth of the etching solution at a processing plane of layered substrate **3** while pressure in the etching holder **50** is substantially at atmospheric pressure when the etching holder **50** holding the layered substrate **3** is sunk in the etching solution. Because of that, there has been problems that etching is performed unevenly and the substrate itself is broken by stress corresponding to a difference in pressure applied to both main surfaces.

When temperature of etching solution, gas in the etching holder **50** gradually expands thermally, and pressure applying to non-processing surface of the layered substrate **3** gradually increases. There has been a problem that stress toward reverse direction to the above-mentioned appears at the layered substrate **3** when pressure applied to the non-processing surface becomes higher than pressure applied to a processing surface corresponding to depth in the etching solution.

An object of the present invention is to provide a semiconductor manufacturing device substantially adjusting pressure applied to a non-processing surface to a processing surface of a semiconductor substrate in wet-etching in which the processing surface of the semiconductor substrate is exposed outside and the non-processing surface is sunk in etching solution so as to be sealed from outside preventing from inflow of the solution to solve the above-mentioned problem in the prior art.

SUMMARY OF THE INVENTION

To achieve the above-mentioned object, the present invention is characterized by providing a substrate holding member for holding the semiconductor substrate so that one main surface of the substrate exposes outside and the other main surface exposes in a space sealed to prevent inflow of liquid from outside, and a pressure control means for controlling pressure in said space so that similar pressure as pressure applied to the one main surface of said semiconductor substrate is applied to the other main surface in performing wet etching only on the one main surface of the semiconductor substrate.

According to the above-mentioned configuration, since similar pressure as pressure applied to one main surface is applied to the other main surface of the semiconductor substrate, stress caused by difference of pressure applying to each main surface does not appear at the semiconductor substrate.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a sectional view showing a construction of main portion of an etching holder according to an embodiment of the present invention.

FIG. **2** is a view showing hole construction and how to use a semiconductor manufacturing device of the present invention including the etching holder.

FIG. **3** is a sectional view showing a second embodiment according to the present invention.

FIG. **4** is a sectional view showing a third embodiment according to the present invention.

FIG. **5** is a sectional view showing how to use of the third embodiment according to the present invention.

FIG. **6** is a sectional view showing a construction of and how to use a fourth embodiment according to the present invention.

FIGS. **7**A to **7**D are sectional views showing a method of processing the conventional cantilever as a specimen.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to the figures, the present invention will be described in detail. FIG. **1** is a plane view showing a construction of a main portion of an etching holder according to an embodiment of the present invention. FIG. **2** is a view showing a whole construction of and how to use of a

semiconductor manufacturing device the present invention including the etching holder of FIG. **1**.

An etching holder **10** of the present invention comprises a ring-shaped substrate holding member **11** having an opening portion at a center thereof, a ring-shaped substrate holding member **12** having an opening portion expanding step by step toward one main surface, and screws **15** fixing mutually each of the substrate holding members **11** and **12** through an O-ring. To an opening of said substrate holding member **12**, one end of a gas passageway **13** is connected, and to the other end, pressurizing means comprised of a pressure control device **14** is connected as shown in FIG. **2**.

In the configuration, a semiconductor substrate **20** exposes outside at processing surface **20***a* thereof and is held by the substrate holding members **11** and **12** through the O-ring **18** so that non-processing surface **20***b* exposes in a cavity or space **16** sealed from outside preventing inflow of the solution as shown in FIG. **1**. The etching holder **10** holding the substrate holding member **20** is sunk in etching solution **40** of an etching vessel **70** as shown in FIG. **2**.

In the etching solution **40**, pressure A is applied to the processing surface **20***a* of the semiconductor substrate **20** corresponding to the depth of the etching solution **40**. The pressure control device **14** applies pressure in the space **16** of the etching older **10** through gas passage **13** so that the similar pressure B as said pressure A is applied to the non-processing surface **20***b* of the semiconductor substrate **20**.

As the pressure A applied to the processing surface **20***a* of the semiconductor substrate can be easily obtained as a function of position (depth) of the semiconductor substrate **20** in the etching solution **40** and the specific gravity of the etching solution **40**, the pressure control device can control pressure linearly in the space **16** if the specific gravity of the etching solution and depth of the substrate are always constant.

According to the present embodiment, as the similar pressure as pressure applied to the processing surface **20***a* is applied to the non-processing surface **20***b* of the semiconductor substrate **20**, stress caused by difference of pressure applied to each main surface at the semiconductor substrate **20** is prevented.

If a pressure sensor for detecting pressure applied to the processing surface **20***a* of said semiconductor substrate **20** is additionally formed so that said pressure control device **14** controls the application of pressure in the space **16** corresponding to an output signal of said pressure sensor, pressure applied to the non-processing surface **20***b* can always be controlled accurately independent of the specific gravity of the solution and depth of the substrate.

FIG. **3** is a plane view showing a construction of a main portion of an etching holder according to a second embodiment of the present invention. The same symbols in FIGS. **1** and **2** as said symbols show the same or similar parts.

The present embodiment is characterized by that an exhaust valve **80** opening and exhausting gas in a space **16** when pressure in the space **16** is over a predetermined value is formed. The threshold value of pressure at which the exhaust valve **80** opens is previously set so that difference between pressure A applied to a processing surface **20***a* of a semiconductor substrate **20** and pressure B applied to a non-processing surface **20***b* is less than value having a bad influence to the semiconductor substrate **20**.

According to the present embodiment, when pressure B applied to the non-processing surface **20***b* of the semiconductor substrate **20** becomes higher than pressure A applied to the processing surface being over the predetermined value by expansion of gas in the space **16** because of high temperature of the etching solution, the exhaust valve **80** opens and gas in the space **16** is exhausted so that pressure B applied to the non-processing surface **20***b* decreases. Therefore, stress does not appear at the semiconductor substrate even when temperature of the etching solution is high.

FIG. **4** is a plane view showing a construction of a main portion of an etching holder according to a third embodiment of the present invention. The same symbols as said symbols of FIGS. **1** and **3** show the same or similar parts. The present embodiment is characterized by that a piping **90** is formed for generating pressure corresponding to a depth of a substrate in the etching solution into said space **16**. One end of said piping **90** is connected in gas-tight to an opening **19** of said substrate holding member **12**, and the other end leads to an opening end **90***a* through a U-shaped pipe portion **90***b*.

In the configuration, etching solution flows in the piping **90** from the opening end **90***a* when the etching holder holding the semiconductor substrate **20** similarly as said embodiment is sunk in etching solution **40** as shown in FIG. **5**. As the result, pressure corresponding to a liquid-level of the etching solution is applied to the non-processing surface **20***b* by the etching solution **40** flowing from the opening end **90***a* based on Pascal's principle.

Because of that, if the position of the opening end **90***a* is previously determined based on the specific gravity of the etching solution and depth of the substrate so that the liquid-level of the etching solution flowing from the opening end **90***a* becomes the same level as the processing surface **20***b* of the semiconductor substrate **20**, it is possible make pressures applied to the processing surface **20***a* and non-processing surface **20***b* of the semiconductor substrate **20** substantially equal.

Although it is described that the position of the opening end **90***a* is previously fixed, it is possible make pressures applied to the processing surface **20***a* and non-processing surface **20***b* of the semiconductor substrate **20** substantially the same pressure without relation to the specific gravity of the etching solution by adjusting properly a distance **90***c* corresponding to the specific gravity of the etching solution if distance **90***c* between the U-shaped pipe portion **90***b* and the opening end **90***a* can be freely adjusted.

FIG. **6** is a plane view showing a construction of a main portion of an etching holder according to a fourth embodiment of the present invention. The same symbols as said symbols of the previous figures show the same or similar parts.

The present embodiment is characterized by that a piping **95** which one end thereof is connected to an opening **19** of a substrate holding member **12** in gas-tight and the other end of which is opened outside is formed. Said piping **95** is constructed so that the other end of the piping exposes in the air outside when the etching holder sunk in the etching solution **40**.

According to the present embodiment, it is possible make pressures applied to the processing surface **20***a* and non-processing surface **20***b* of the semiconductor substrate **20** substantially the same pressure without relation to temperature of the etching solution **40** by holding the etching holder at a comparatively shallow position in the etching solution **40** as shown in the figure because the inside of the space **16** is always kept in atmospheric pressure even if temperature of the etching holder increases due to the etching solution **40**.

According to the present invention, in the wet etching process in which the semiconductor substrate is sunk in the etching solution being held so that the processing surface thereof is exposed and the non-processing surface is sealed preventing inflow of the etching solution, pressure applied to the processing surface can be matched to pressure applied to the non-processing surface. Therefore, stress does not appears so that uneven etching and breakage of the substrate is prevented.

What is claimed is:

1. A semiconductor manufacturing device for performing wet etching on only one main surface of a semiconductor substrate, the semiconductor manufacturing device comprising:

a substrate holder for holding a semiconductor substrate to form an open space and a sealed space so that a first main surface of the semiconductor substrate is exposed to the open space and a second main surface of the semiconductor substrate opposite to the first main surface is exposed to the sealed space, and for maintaining the semiconductor substrate immersed in an etching solution so that the first main surface of the semiconductor substrate is exposed to the etching solution and subjected to wet etching and the etching solution does not flow into the sealed space; and

pressure control means for controlling a pressure in the sealed space to a pressure substantially equal to a pressure applied to the first main surface of the semiconductor substrate when the semiconductor substrate is immersed in the etching solution.

2. A semiconductor manufacturing device according to claim **1**; wherein the pressure control means comprises a gas passageway having one end connected with a gas-tight connection to the sealed space and a second end, and pressurizing means connected with a gas-tight connection to the second end of the gas passageway for pressurizing the sealed space through the gas passageway to maintain the pressure in the sealed space substantially equal to the pressure applied to the first main surface of the semiconductor substrate.

3. A semiconductor manufacturing device according to claim **2**; further comprising a pressure sensor for detecting the pressure applied to the first main surface of the semiconductor substrate; and wherein the pressurizing means pressurizes the sealed space in accordance with the pressure detected by the pressure sensor.

4. A semiconductor manufacturing device according to claim **1**; wherein the pressure control means comprises an exhaust valve for exhausting gas from the sealed space to the exterior of the semiconductor manufacturing device when the pressure in the sealed space exceeds a predetermined value.

5. A semiconductor manufacturing device according to claim **1**; wherein the pressure control means comprises a piping having a first end connected to the sealed space with a gas-tight connection and a second end opposite the first end; wherein when the semiconductor substrate is maintained immersed in the etching solution by the substrate holder the piping is also immersed in the etching solution so that a pressure substantially equal to the pressure applied to the first main surface of the semiconductor substrate is applied to the sealed space by the etching solution through the piping.

6. A semiconductor manufacturing device according to claim **1**; wherein the pressure control means comprises a piping having a first end connected to the sealed space with a gas-tight connection and a second end opposite the first end; wherein when the semiconductor substrate is maintained immersed in the etching solution by the substrate holder the second end of the piping is exposed to air pressure outside of the etching solution.

7. A semiconductor manufacturing device according to claim **1**; wherein the substrate holder comprises a first holding member and a second holding member connected to the first holding member for holding the semiconductor substrate, the first holding member having a central opening for exposing the first main surface of the semiconductor substrate to the etching solution, and the second holding member having a step portion for supporting the semiconductor substrate and a cavity corresponding to the sealed space.

8. A semiconductor manufacturing device according to claim **7**; wherein each of the first and second holding members is generally ring-shaped.

9. A semiconductor manufacturing device according to claim **7**; wherein the substrate holder further comprises first and second sealing members for preventing the inflow of etching solution into the sealed space, the first sealing member providing a liquid-tight seal between an outer peripheral portion of the first main surface of the semiconductor substrate and the first holding member, and the second sealing member providing a liquid-tight seal between the first and second holding members.

10. A semiconductor manufacturing device according to claim **9**; wherein each of the first and second sealing members comprises an O-ring.

11. A semiconductor manufacturing device according to claim **10**; wherein each of the first and second holding members is generally ring-shaped.

12. A semiconductor manufacturing device according to claim **9**; wherein each of the first and second holding members is generally ring-shaped.

13. A semiconductor manufacturing device comprising:

a holder having an open end, a cavity, a support surface for supporting a semiconductor substrate between the open end and the cavity so that a first main surface of the semiconductor substrate is exposed to the open end and a second main surface of the semiconductor substrate opposite the first main surface is exposed to the cavity, and sealing means for sealing the cavity to prevent the inflow of an etching solution into the cavity when the holder supporting the semiconductor substrate is immersed in the etching solution while the etching solution is allowed to pass through the open end to subject the first main surface of the semiconductor substrate to wet etching; and

pressure control means for controlling a pressure in the sealed cavity to a value substantially equal to a pressure applied to the first main surface of the semiconductor substrate when the holder supporting the semiconductor substrate is immersed in the etching solution.

14. A semiconductor manufacturing device according to claim **13**; wherein the pressure control means comprises a gas passageway having one end connected with a gas-tight connection to the sealed cavity and a second end, and pressurizing means connected with a gas-tight connection to the second end of the gas passageway for pressurizing the sealed cavity through the gas passageway to maintain the pressure in the sealed cavity substantially equal to the pressure applied to the first main surface of the semiconductor substrate.

15. A semiconductor manufacturing device according to claim **14**; further comprising a pressure sensor for detecting the pressure applied to the first main surface of the semi-

conductor substrate; and wherein the pressurizing means pressurizes the sealed space in accordance with the pressure detected by the pressure sensor.

16. A semiconductor manufacturing device according to claim **13**; wherein the pressure control means comprises an exhaust valve for exhausting gas from the sealed cavity to the exterior of the semiconductor manufacturing device when the pressure in the sealed cavity exceeds a predetermined value.

17. A semiconductor manufacturing device according to claim **13**; wherein the pressure control means comprises a piping having a first end connected to the sealed cavity with a gas-tight connection and a second end opposite the first end; wherein when the semiconductor substrate is maintained immersed in the etching solution by the substrate holder the piping is also immersed in the etching solution so that a pressure substantially equal to the pressure applied to the first main surface of the semiconductor substrate is applied to the sealed cavity by the etching solution through the piping.

18. A semiconductor manufacturing device according to claim **13**; wherein the pressure control means comprises a piping having a first end connected to the sealed cavity with a gas-tight connection and a second end opposite the first end; wherein when the semiconductor substrate is maintained immersed in the etching solution by the substrate holder the second end of the piping is exposed to the exterior of the semiconductor manufacturing device and the etching solution.

19. A semiconductor manufacturing device according to claim **13**; wherein the holder comprises a first holding member having the open end, and a second holding member having the cavity and the support surface and connected to the first holding member.

20. A semiconductor manufacturing device according to claim **19**; wherein each of the first and second holding members is generally ring-shaped.

21. A semiconductor manufacturing device according to claim **19**; wherein the sealing means comprises a first sealing member for providing a liquid-tight seal between an outer peripheral portion of the first main surface of the semiconductor substrate and the first holding member, and a second sealing member for providing a liquid-tight seal between the first and second holding members.

22. A semiconductor manufacturing device according to claim **21**; wherein each of the first and second sealing members comprises an O-ring.

23. A semiconductor manufacturing device according to claim **21**; wherein each of the first and second holding members is generally ring-shaped.

24. A semiconductor manufacturing device according to claim **20**; wherein each of the first and second holding members is generally ring-shaped.

* * * * *